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On Rates of Linear and Weight Growth of Scotian Silver Hake (Merluccius bilinearis Mitch.)

by

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INTRODUCTION

The Scotian silver hake is one of the most important commercial species in the international fisheries. Optimization of the fishing for this species and development of measures for management of biological resources in this region must be scientifically based. For stock and allowable catch assessment, the data on catch composition, mortality, parameters which characterize the growth, etc. are required. The studies of age composition and rate of growth relative to body length and weight are very significant. For instance, Waldron and Fanning (1986) reported that the increase of the mean weight by age is indicative of the fact that the population had been underexploited.

The data on the growth of hake have been reported by the Canadian, Soviet and Cuban investigators. The authors made calculations mainly regardless of the sex. As to the Canadian data (Waldron and Fanning, 1986; Waldron, Fanning, Bourbounais, Shoneell, 1988), the figures of the mean weight by age give rise to doubts as they result from the "length-weight" relationship. To obtain precise estimates of the growth of the fish in the population and reliable data on mean weight, which are essential for stock assessment we also attempted to determine the parameters of the growth equation according to Bertalanffy, separately by sex, for mean body length and weight.

MATERIALS AND METHODS

All the data were adopted from the AtlantNIRO archives. Among them are the data used for:

- estimating the length by age for the 1984-1985 period (182 592 specimens);

- estimating the mean weight by age and sex for the 1978-1986 period (5 165 specimens).

The weight, length and parameters of the Bertalanffy's equation were estimated separately for males and females. The least squares method was used to calculate the coefficients of the "length-weight" relationship. Several variants with differing number of age groups were used to determine the parameters W_∞ , L_∞ , K and t_o .

RESULTS AND DISCUSSION

1. Rates of growth of body length and weight.

Linear growth of the Scotian silver hake in 1975 and over the 1983-1985 period are presented in table 1, and the graph of its variation is shown in fig. 1.

The largest yearly linear growth increment takes place during the first year of life. The intensive growth persists till the fish is two and a half years of age. The linear growth slackens in the third year of life when maturation of gonads occurs. Such a rate of growth persists in the males and females till they are four years old. At the age of five and older the rate of growth increases again.

In the first and second years of life, actually no difference in the rate of growth exists between the males and females. The females begin to grow faster in the third year of life, this tendency persisting to the end of their life. In general, a tendency of variation of the length by age is similar for both sexes: the curve is negatively exponential in first three age groups, and positively exponential afterwards. In samples, the females to nine years of age are common, sometimes ten or eleven year old specimens occur and individually the specimens of twelve years old while the males are mainly represented by the four year old specimens and individually by seven year old specimens. The only observed case of occurrence of an eight year old male was in 1985.

The maximum length of the females in the samples was 67 cm, and that of the males - 40 cm.

The rate of growth of the hake weight differs from the linear growth. The mean body weight of the males in the first year of life is somewhat larger than in the females (50 g and 47 g, respectively). Beginning from the age of two, however, the weight of the females exceeds that of the males. Later it gradually increases in the females, and after they are six year old, when almost all males perish, the mean weight sharply increases, in particular, at the age of eight, nine and ten.

The mean weights of the hake by age over the 1978-1986 period are given in table 2. The graph of variation of the weight by age is shown in fig. 2. The curve of age and weight for the males is rectilinear for the first four years of life and negatively exponential afterwards. For the females, the curve is also almost straight during the first four years and positively exponential afterwards. A sharp increase of the weight in the females in the late years of life can be probably attributed to the fact that the proportion of the fish and squids in their ration increases with the growth of length. According to Vinogradov (1982), the females of the maximum size are exclusively ichthyophagous and are apt to excessive cannibalism. The males do not change their food spectrum with age feeding mostly on the euphausiids and on the fish to a lesser degree. Therefore the growth pattern of the silver hake needs to be studied separately by sex.

There exist the other differences between our and Canadian data. They will be dealt with in another paper.

2. "Length-weight" relationship.

The correlation between the length and weight of the silver hake was studied from the data for the 1984-1986 period.

The "length-weight" relationship is described by the formula:

$$W = a \cdot L^b,$$

where W is the body length weight, g ,

L is the length, cm,

a, b are the coefficients.

On calculating these coefficients using the least squares method and substituting them into the formula, it reads:

- total

$$\ln W = \ln a + b \ln L$$

$$\ln W = \ln 0{,}0012 + 3{,}5145 \cdot \ln L$$

$$W = 0.0012 \cdot L^{3.5145}$$

Standard error SD%=2.97%

- for males:

$$W = 0.0029 \cdot L^{3.2307}$$

SD% = 7.29%

-for females:

$$W = 0.0011 \cdot L^{3.5333}$$

SD% = 3.1

As is evident, the weight increases faster in the females than in the males, and, in general, the weight of the hake increases faster in the late years of life (greater than the *exponent* - 3.2307 and 3.5333).

The graph of the "length-weigth" relationship is shown in figs. 3 and 4. Mari and Saba (1978) examined a total of 375 specimens, with 96 males and 236 females ratio. The fish were sampled during one cruise of the ship "Isla de la Juventus". The reported formula was as follows:

$$W = 0.002865 \cdot L^{3.225476}$$

3. Bertalanffy's growth equation.

For assessment of the optimum catch size, the mathematical expression of the growth is required, which may both characterize the initial data and be useful in the analytical study of the growth. The Bertalanffy's equation satisfies all these requirements (Von Bertalanffy, 1934, 1938).

$$L_t = L\infty \cdot (1 - e^{-k(t-t_o)})$$

$$W_t = W\infty \cdot (1 - e^{-k(t-t_o)})^3$$

As it has already been stated, the parameters K, t_o, L_∞ and W_∞ were calculated using different variants.

3.1. For females:

four variants were used: 7, 8, 9 and 10 age groups resulting in different growth equations.

It has been found that the more the number of age groups the smaller the difference between the actual and theoretical values for the older age groups; therefore, we selected the variants with nine age groups:

W_∞ = 115111.8 g K = 0.019 t_o = - 3.4

L_∞ = 103 cm K = 0.054 t_o = - 3.1

3.2. For males:

just one variant was used: six age groups resulting in:

W_∞ = 435.8g K= 0.3453 t_o= -0.9

L_∞ = 43.3 cm K= 0.2507 t_o= -1.6

It is known that for the biological organisms, in general, and for the fish, in particular, the curves of the growth represent an assymetrical sigmoide with an extended right branch (Roice, 1975; Ricker, 1983). However as stated by Nikolsky (1974), the existence of the common formula of growth which would satisfactorily characterize the growth of the majority of fish species at all developmental stages of the ontogenesis is impossible, though the formula of the Bertalanffy's equation yields satisfactory results.

As can be seen, of all the variants for the females the only variant II evidently suits the parameters W , L , k and t_o. It is indicative of the fact that the growth increment in the silver hake females submits to the regularities of growth as per the Bertalanffy's growth equation until they are eight and then proceeds faster. The calculation yielded increadible results. It can be assumed that in females, the growth curve from the Bertalanffy's equation reflects only early and middle developmental stages in the ontogenesis when it still remains positively exponential; at later stages it may turn out to be negative and approach the asymptote, however, the hake do not live to that moment.

In the males, the theoretical asymptotic growth by weight and length is consistent with the data. The equation for the Scotian silver hake male growth reads:

$$L_t = 43.3\ (I - e^{-0.2507(t+1.6)})$$

$$W_t = 435.8\ (I - e^{-0.3453(t+0.9)})^3$$

At the age $t = \frac{1}{K} + t_o$, the hake attain 0.63 L and 0.25 W as

$$L_t = L(1-e^{-1}) = 0.63\ L_\infty$$

$$W_t = W_\infty(1-e^{-1}) = 0.25\ W_\infty$$

The inflection point in the silver hake males occurs when they attain the length of 27.3 cm and the weight of 109 g (at the age of 2).

For the females, the equation is as follows:

$$L_t = 103\ (I - e^{-0.0544\ (t+3.1)})$$

$$W_t = 115111.8\ (I - e^{-0.019(t+3.4)})^3$$

SUMMARY

The peculiarity of the silver hake growth is that the males grow slowlier than the females and live four years in mass while the females grow faster and live to six years in mass. The rates of linear and weight growth of the females do not slacken with age, which can be explained by a transition to intensive feeding on the fish at older age.

The "length-weight" ratio with a greater index in the power (b = 3.5145) showed that the curve of this relationship for the hake is more rounded than for the other fish species. The curve is more rounded for the females than for males.

The parameters of the Bertalanffy's growth equation (W_0 and L_∞) appear to be realistic for the males while for the females these values are considered to be formal and theoretical, though the equation itself is reliable enough.

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Table 1

Length (cm) of the Scotian silver hake by age

Year	Sex	Age 1	2	3	4	5	6	7	8	9
1981	♂	20.4	27.5	29.9	32.0	34.4	36.5			
	♀	19.8	27.7	31.0	32.6	36.0	38.5	41.1	46.0	52.0
	♂♀	20.1	27.5	30.3	32.3	35.8	38.0	41.1	46.0	52.0
1982	♂	20.1	26.5	30.0	32.1	34.8	36.8			
	♀	20.0	27.0	31.4	33.5	36.0	37.4	42.3	43.2	49.6
	♂♀	20.0	26.7	30.5	32.8	35.8	37.4	42.3	43.2	49.6
1983	♂	19.4	25.8	29.8	31.9	34.6	37.3			
	♀	20.2	26.3	30.4	33.0	36.3	39.5	43.0	47.1	50.9
	♂♀	20.2	26.3	30.0	32.5	36.1	39.6	43.0	47.1	50.9
1984	juv.	21.1	23.5							
	♂	20.7	27.7	29.8	32.0	35.2	37.0			
	♀	20.5	26.4	30.6	32.8	35.9	38.3	41.5	45.0	47.0
	♂♀	20.8	26.8	30.1	32.4	35.8	38.3	41.5	45.0	47.0
1985	♂	21.0	26.8	29.9	32.9	35.3	37.8			
	♀	21.3	27.4	30.4	33.3	37.6	41.2	43.9	47.1	51.9
	♂♀	21.1	27.0	30.2	33.1	37.1	41.0	43.9	47.1	51.9
Mean	♂	20.3	26.9	29.9	32.2	34.9	37.1			
	♀	20.4	27.0	30.8	33.0	36.4	39.0	42.4	45.9	50.3
	♂♀	20.3	26.9	30.2	32.6	36.1	38.9	42.4	45.9	50.3

Table 2

Weight (g) of the Scotian silver hake by year

Year	Sex		Age 1	2	3	4	5	6	7	8	9	10
1978	♀	n	18	56	62	54	37	25	31	27	9	
		M	61	118	162	307	356	453	**602**	755	1049	
	♂	n	11	56	93	43	11					
		M	76	127	231	304						
1979	♀	n	18	39	24	20	16	19	**15**	12	6	3
		M	71	156	242	367	411	584	**722**	**946**	1298	1310
	♂	n	9	35	33	33	4					
		M	73	165	226	292	337					
1980	♀	n	49	54	67	102	85	56	**84**	100	89	45
		M	39	129	199	252	363	455	522	810	1276	1536
	♂	n	49	111	70	32	3					
		M	38	121	185	245	277					
1981	♀	n	49	33	95	122	71	46	54	52	41	16
		M	33	105	188	239	334	413	564	799	1214	1502
	♂	n	30	165	146	83	6	4				
		M	69	113	163	216	252	311				

Table 2 (continued)

Year	Sex		Age 1	2	3	4	5	6	7	8	9	10
1982	♀	n	30	37	27	41	27	8	36	24	38	15
		M	41	120	232	283	392	430	640	729	1087	1538
	♂	n	23	81	39	16	3	1				
		M	47	124	179	228	273	440				
1983	♀	n	29	92	28	53	39	27	13	1	1	
		M	44	120	187	270	364	471	632	1080	1133	
	♂	n	45	107	74	52	7	2				
		M	44	86	189	233	281	380				
1985	♀	n	87	89	58	109	66	40	36	23	19	
		M	59	135	190	290	392	474	642	771	1113	
	♂	n	43	86	58	44	17	18	6	1		
		M	53	87	148	213	277	316	373	653		
1986	♀	n	78	69	60	44	44	17	19	9		
		M	44	128	187	273	399	487	634	957		
	♂	n	70	74	69	29	8					
		M	47	111	168	236	298					
Mean	♀	n	358	469	411	491	385	238	2888	248	206	78
		M	47	127	197	264	370	459	591	803	1186	1523
	♂	n	280	715	582	332	59	25				
		M	50	112	176	235	292	325				

n = number of specimens

M = mean weight value

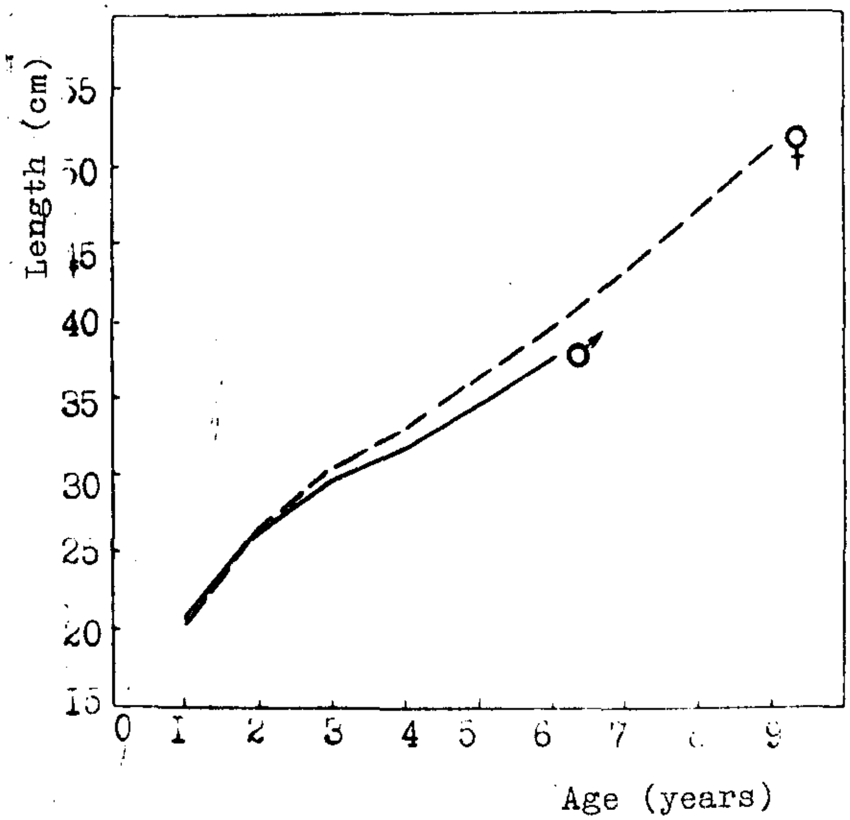
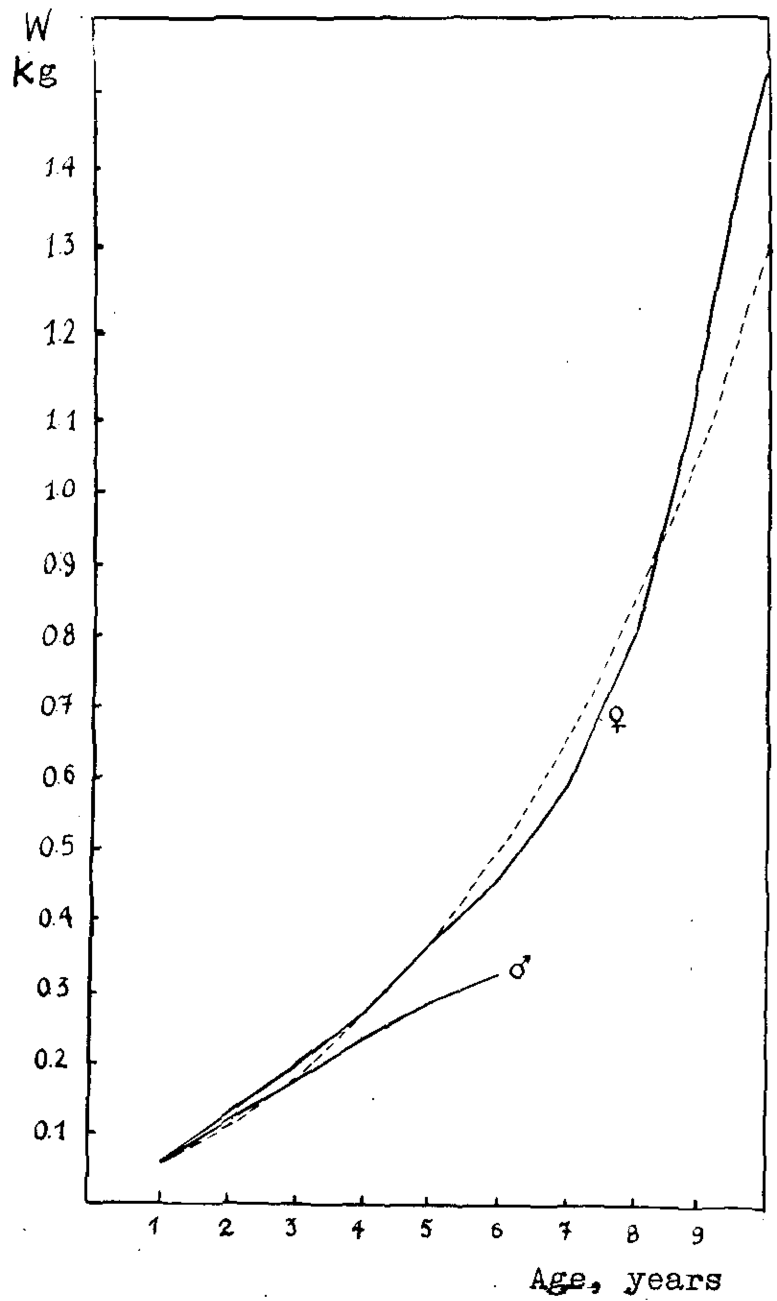


Fig. 1. Yearly increase of the Scotian silver hake males and females length (in 1981 to 1985).



—— Actual

---- Theoretical line

Fig. 2. Yearly increase of the Scotian silver hake weight (in 1978 to 1986).

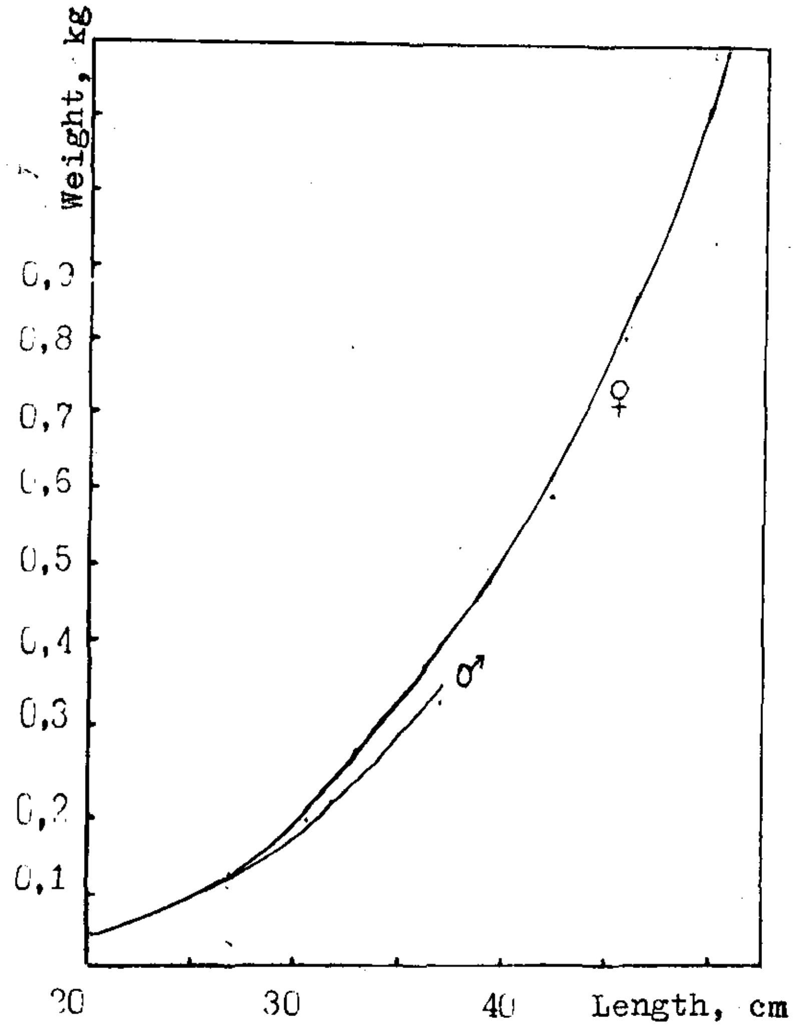


Fig. 3. Length and weight of the Scotian silver hake in 1978 to 1986.

for males $W = 0.0029 \cdot L^{3.23\,?\,7}$ [illegible]

for females $W = 0.0011 \cdot L^{3.5333}$

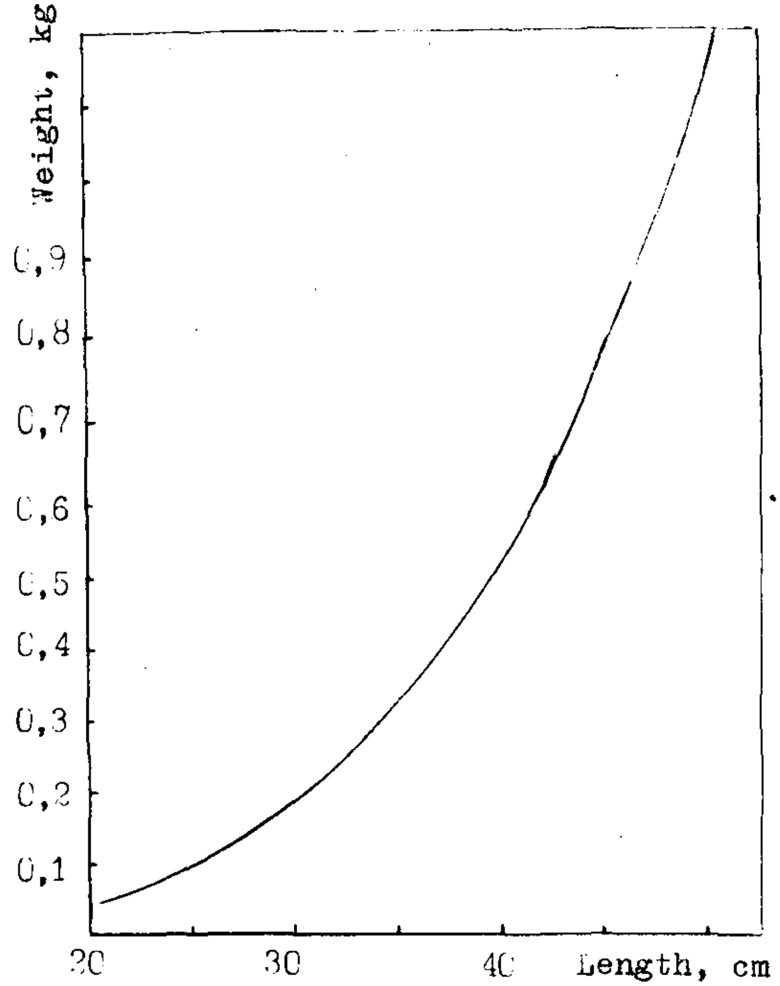


Fig. 4. Length and weight (total) $W = 0.0012 \cdot L^{3.5145}$

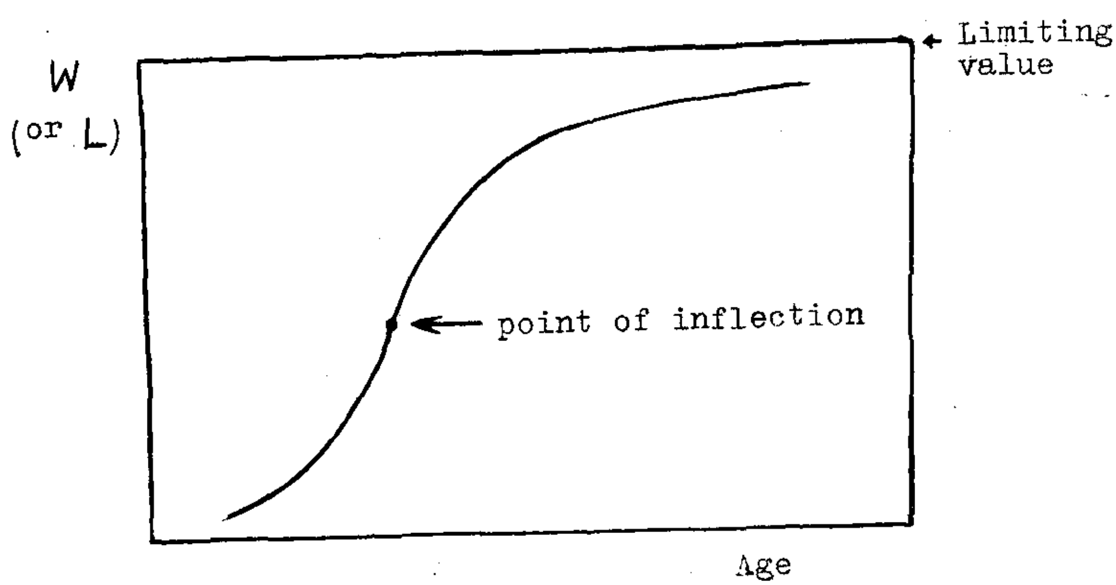


Fig. 5. Typical curve of increase of aquatic animal growth. Inflection point usually occurs in the first half of life at $W_t = 0.296\ W_\infty$ (According to von Bertalanffy).